

**Log Pond Restoration Project: Structure and Function of the Benthic
Community – Year 2 report**

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Introduction

As part of the comprehensive plan to clean up sediments and restore habitat in Bellingham Bay, the Georgia Pacific Log Pond was capped with clean sediment. The initial capping, which occurred in 2000, involved covering existing sediments with a thick layer of clean sediment followed by a thinner layer of native silt material. It was expected that the native silt would already contain local infaunal invertebrates and would provide good settlement habitat for larvae from other regional invertebrate species.

The Log Pond restoration plan requires assessment of the new habitat performance. While capping the sediments in the pond should improve sediment quality, it is important to demonstrate that a healthy, productive benthic community is developing in the restored site. This is important both for the inherent value of the benthic invertebrate community itself and for the role it plays in the broader Bellingham Bay and regional ecosystems (e.g., as food for juvenile salmonids).

Sampling done 5-6 months after installation of the cap revealed a developing invertebrate community in the Log Pond (Bingham et al., 2001). The Log Pond and the Chuckanut reference sites held similar numbers of species, had similar levels of diversity and evenness, and had similar levels of invertebrate biomass. While diversity/evenness indices and biomass measurements indicated that the communities at the two sites were similar, other analyses showed that the populations were not the same. In particular, cluster analyses clearly separated the two sites, indicating that the Chuckanut sites were much more similar to each other than they were to the Log Pond sites. The effect resulted from differences in the species that occurred in the two locations. For example, the Chuckanut sites were dominated by crustaceans while the Log Pond held a much higher proportion of polychaete annelids.

Given the patchiness of invertebrate recruitment in space and time, the differences we saw in these communities in our sampling may have simply resulted from the failure of settling larvae to reach the Log Pond within the first 5 months after capping. If this is the case, we might expect to see more convergence in the two sites after an additional year of recruitment has occurred. The goals of the present study were 1) to determine how the invertebrate community had changed over the 12 months since the first sampling and 2) to determine how closely the Log Pond community resembles the undisturbed community in the Chuckanut reference site a full 18 months after capping was done.

Materials and Methods

To ensure that data collected in Year 2 were comparable to those collected in the Year 1 sampling, we used the same collection methods (full details in Bingham et al., 2001).

Quantitative sampling of the epibenthos

The epibenthic community was sampled with an epibenthic suction pump as described by Simenstad et al. (1991). Three replicate 0.033 m² samples were taken at each of 3 fixed stations (SS74, SS75 and SS76) within the log pond (Fig. 1). These are

the same locations that were sampled in the Year 1 work. We washed the samples through a 0.253-mm mesh sieve, preserved them in 10% buffered formalin and later transferred them to 70% ethanol.

For comparison with the Log Pond, samples were also taken at a reference site in the inner part of Chuckanut Bay (Fig. 1). Triplicate samples at stations CH1 and CH2 (the same stations sampled in the Year 1 study) were taken as described above. The Log Pond and Chuckanut sites were sampled on May 14 and again on June 24, 2002.

In the laboratory, all invertebrates were picked from the samples, sorted and identified to the lowest taxonomic level. To determine biomass composition of each sample, we separated the invertebrates into broad taxonomic groups (i.e., nematodes, annelids, mollusks, crustaceans and echinoderms). These grouped samples were dried in a 60° C oven for 24 hours then weighed.

For each sample, we calculated the total number of invertebrate species, the Shannon-Weiner diversity index (H' , using log base e) and Pielou's evenness index (J'). To look for differences between the two study sites and between the two sampling dates, we used a 3-way partially nested analysis of variance. Time and Site were fixed main effects. Station (e.g., SS74, CH1) was a random factor nested within site. We used the same model to test for differences in total invertebrate biomass. Where the ANOVA assumption of equal variances was violated, we attempted to correct the violation by transforming the data. If that was unsuccessful, we continued with the analysis, realizing that our analyses would suffer from an increased possibility of Type I error (i.e., finding significant differences that were not really there).

Quantitative sampling of benthic invertebrates

As in Year 1 (and the baseline sampling), we used a 0.023 m² petite ponar grab sampler (PSEP 1997a) to collect benthic invertebrates. On each sampling date, three replicate samples were taken at each station in the log pond (SC-74, SC-75, SC-76) and at the Chuckanut Bay reference stations (CH1, CH2). All ponar samples were collected on June 24, 2002.

The collected samples were washed through a 0.5-mm brass sieve and fixed with 10% buffered formalin. They were later transferred to 70% ethanol, sorted and identified to the lowest possible taxonomic group. After we had sorted and counted all the invertebrates, we grouped them into taxonomic groups, oven dried them at 60° C for 24 hours then weighed them to get a dry biomass measurement. A large proportion of the biomass in some samples was due to a single polychaete (*Owenia fusiformis*). This species lives in tubes it constructs of sand and mucous. Unfortunately, it was not possible to remove the worms from their tubes making it difficult to get an accurate measure of the actual biomass. To give us maximum flexibility for data analysis and presentation, we weighed the *O. fusiformis* separately from other polychaetes. To compare total invertebrate biomass in the Log Pond and Chuckanut sites, we summed total biomass (including *O. fusiformis*) at each station, log transformed the data (to homogenize the variances) and tested for site and station differences with a 2-way nested ANOVA (with station nested in site).

Community analyses

We ran cluster analyses to get a better idea of similarities between the invertebrate communities in the Log Pond and in Chuckanut Bay. These analyses go beyond simple counts of species, diversity indices and evenness indices as they consider the species composition of the samples (which may indicate interactions among species or common responses to environmental characteristics).

We used hierarchical cluster analysis (Ward's method with a Euclidean distance measure) and k-means cluster analysis to reveal patterns in the data. We ran separate analyses for epibenthic data (all stations in both May and June) and for the ponar data (all stations on the single June sampling date).

Characterization of the sediments

Because sediment composition can have a strong impact on benthic community structure and composition, we felt it was important to characterize the sediments. To do this, we took a single ponar bottom grab from each station on June 24, 2002. The sediments were held in a -80° C freezer until they could be processed. At that time, the samples were washed through a series of sieves that separated the sediment into size fractions. The fractions were oven dried at 60° C for 48 hours and weighed. We used the weights to determine the grain-size composition for each sample. A subsample of the unsorted sediment was also oven dried for 96 hours at 60° C, weighed, and burned at 500° C in a muffle furnace to remove all organic material. The drop in weight was used to calculate a percent organic content.

To determine whether sediment composition was different between the Log Pond site and the reference site, we calculated the average percent composition for each sediment fraction at each site. We then compared the sediment size distributions for the two sites with a Kolmogorov-Smirnov test. Organic fraction was compared with a one-way analysis of variance with site (Log Pond vs. Chuckanut) as the main effect.

Results

Biomass measurements

Statistical analysis of epibenthic invertebrate biomass failed to show any significant differences between the Log Pond and Chuckanut reference communities (Table I). While none of the effects were significant, the power of this analysis was quite low, reflecting the low replication and imbalance in the design (i.e., 9 samples in the Log Pond and only 6 in the Chuckanut reference site). An examination of the data suggests that there may, in fact, be differences among the stations in the Log Pond (Fig. 2). The SS75 station (Fig. 1), in particular, stands out in both the May and June samples. This station is deeper than the other two Log Pond sites and appears, in the Year 2 sampling, to be distinctly different.

The biomass of benthic invertebrates in the ponar samples showed strong differences among stations (though there were no statistically significant site effects, Table II). Once again, the SS75 station stood out dramatically (Fig. 2). The dramatic

difference in this site was partially due to the polychaete *Owenia fusiformis*, which was extremely abundant here. The organic dry weight of these samples was overestimated due to the inclusion of their sand tubes in the measurements. However, it is clear from Figure 2 that differences existed even when *O. fusiformis* weights were not included. The invertebrate community at Station SS75 was clearly different from any other station we sampled.

Figure 3 shows how different taxonomic groups contributed to the dry weight biomass of the Log Pond and Chuckanut samples. Several patterns are clear. The first is the shift in epibenthic community composition of samples taken only a month apart, particularly in the Log Pond site. In the May samples, the community (on a weight basis) was composed primarily of annelids. By June, the composition had shifted toward a community with a greater representation of nematodes and crustaceans. These changes were not as clear in the Chuckanut site where the May and June samples were quite similar.

Ponar samples showed differences in the benthic communities at the Log Pond and Chuckanut sites. The Log Pond appeared to hold a greater proportion of annelids while the Chuckanut sites had more molluscs.

Community indices

Epibenthic community

To further evaluate community composition, we examined total numbers of species, diversity and evenness in the epibenthic samples. Statistical analysis showed significant seasonal differences in the number of species with more species in June than in May (Table III, Fig. 4). There was also a significant Time*Site interaction (indicating that the change in number of species was greater at the Chuckanut site than it was in the Log Pond) and a significant Station effect (indicating differences between stations within each site). There was no clear site difference, suggesting that total number of species is similar in the Log Pond and Chuckanut sites. We could detect no significant temporal or spatial differences in diversity or evenness indices (Tables IV - V, Fig. 4). However, power for these analyses was again quite low.

Benthic community

In contrast to the epibenthic samples, ponar samples showed strong patterns in number of species, diversity and evenness. Number of species differed among stations within sites (Table VI, Fig. 5) but there were no differences between the Chuckanut and Log Pond sites. There were, however, site differences in diversity and evenness; both were slightly higher in the Chuckanut site than in the Log Pond (Tables VII - VIII, Fig. 5).

Cluster analyses

Cluster analysis of epibenthic samples showed a strong effect of date on community composition. The analysis produced 4 data clusters (Fig. 6). Cluster 1 was a

peculiar outlier group consisting of one June stations in the Log Pond (SS76). Because this sample stood out so strongly from all other clusters, we removed it and reran the analysis. Removing the sample had no effect on the clustering of the remaining stations so we returned to the original analysis.

Cluster 2 was composed almost entirely of May samples. Clusters 3 and 4 consisted almost exclusively of June samples. The separation of these clusters was largely due to changes in abundance of foraminiferans, nematodes and several crustaceans (*Cumella vulgaris*, *Tisbe* sp., and *Harpacticus* sp.). The strong difference in Cluster 1 appears related to an unusually high number of nematodes and harpacticoid copepods there. It is not clear why this particular station on this date was so different. It is likely that, in our sampling, we simply landed on an unusual habitat patch.

There was no separation of the Log Pond and Chuckanut sites in the cluster analysis, indicating that the epibenthic communities in these sites were similar. This was verified by a chi-square association test in a k-means cluster analysis, which showed no Site contribution to separation of the clusters ($X^2_{8df} = 11.6$, $p = 0.17$).

In contrast to the epibenthic samples, ponar samples showed very strong clustering of sites. The most striking pattern was the clear separation of station SS75 in the Log Pond (Cluster 1, Fig. 6). Clusters 2 and 4 were composed entirely of Chuckanut sites. Cluster 3 contained the remaining Log Pond stations and two samples from Chuckanut station CH2 (Fig. 6). K-means cluster analysis verified the strong contribution of site to the clustering ($X^2_{4df} = 15.0$, $p = 0.004$).

Five species appeared to contribute most strongly to the separation of the ponar clusters. The polychaetes *Nephtys longosetosa*, *Owenia fusiformis*, and *Spirorbis* sp. were particularly important in separating out SS75 (all were much more abundant at SS75 than at any other station). Separation of the remaining clusters was strongly influenced by differing abundances of the crustacean *Cumella vulgaris* and the gastropod *Alvania carpenteri* (*C. vulgaris* was particularly abundant in the Chuckanut sites while *A. carpenteri* was abundant at SS75, SS76, and CH1).

Sediment characteristics

Sediments from both study sites were composed largely of sands in the 0.064 - 0.495 mm size fractions (Fig. 7). Kolmogorov-Smirnov analysis showed that the Log Pond sediments were coarser (i.e., had larger average grain sizes) than the Chuckanut sediments ($D = 0.37$, $p > 0.01$).

The organic content of sediments from all sites was less than 3% (Fig. 7). One-way ANOVA failed to detect significant differences between the study sites ($F_{0.05, 1, 3} = 0.47$, $p = 0.54$). However, power was very low (power = 0.08).

Discussion

Results of Year 2 sampling suggest that a diverse invertebrate community has established itself in the Log Pond site approximately 18 months after it was capped with clean sediment. We could detect no differences in epibenthic or benthic invertebrate biomass between the Log Pond and the Chuckanut Bay reference site. In addition, many of the same species occurred in both habitats (though there were slight differences in their biomass contribution to the invertebrate communities).

While these are good indications that a healthy community is being established in the Log Pond, there are still distinct differences between it and the Chuckanut site. For example, benthic invertebrate diversity and evenness were higher in the Chuckanut site than in the Log Pond. Furthermore, the actual structure of the community appeared to differ in these two sites. In particular, the Chuckanut site seemed to have a better representation of mollusks, while the Log Pond had a higher relative proportion of annelids.

An overriding feature that emerged several times in our analyses was the significant small-scale variability of the invertebrate community at both the Chuckanut and Log Pond locations; we frequently found significant "Station" differences in species abundances, biomass, and community indices. This suggests that the invertebrate communities are patchy in both of these environments. This could reflect small scale differences in sediment composition or in other features of the habitat. The variability could also represent biological features of the habitat. For example, there are many patches of eelgrass (primarily *Zostera marina*) in the Chuckanut site and smaller patches have recently appeared in the Log Pond (P. Schlenger, pers. comm.). If invertebrate communities are responding to such a mosaic of patches, it could well account for the variability we saw in our sampling.

While small-scale patchiness appears important in both sites, it was evident that the variability is greatest in the Log Pond. To determine whether the Log Pond community is converging on the "natural" state represented by the Chuckanut reference site, we performed cluster analyses. The clustering was based only on the species present and their relative abundances (without reference to sites). After the clustering was complete, we overlaid the sample station identifier and looked for patterns. If the habitats are converging, any clusters that formed should have included a random assortment of stations from both Chuckanut and the Log Pond. While this was clearly the case for most of the epibenthic samples (temporal effects were then most important factor controlling the formation of clusters), it was not true for the SS76 station, indicating habitat patchiness. The effect was even more dramatic in the ponar sampling. All clusters had a strong "site" component to them. The most striking effect was the distance of the SS75 samples from everything else in the analysis.

In addition to spatial variability, the Log Pond samples also showed greater temporal variability than the Chuckanut site. Both the invertebrate biomass and community composition seemed to change more between the May and June samples in the Log Pond than they did in the Chuckanut site. This spatial and temporal variability is not surprising given the relatively short time since the Log Pond habitat was created. It is probable that the Log Pond community will continue to change for some time as sediments stabilize, as species not currently represented in the site recruit from the plankton, and as species interactions are influenced by the return of predators (e.g., fish).

Comparison of Year 1 and Year 2 data provides additional information about the changing structure of the invertebrate community in the Log Pond and in the Chuckanut site. Overall examination of the data again suggests considerable temporal variability. The most striking feature was the difference in diversity between the Year 1 and Year 2 data, which occurred in both the Log Pond and Chuckanut sites (Fig 4). It is not clear what factors may have contributed to this difference.

Figure 2 suggests a clearer pattern in the overall invertebrate biomass. Dry weight biomass in both the Log Pond and Chuckanut sites was higher in the second year than in the first. The major difference in the two years appears to be the change in Log Pond Station SS75. We suggest that the enormous change there was due to either 1) the establishment of a new *O. fusiformis* population in the SS75 site or 2) a patchy distribution of *O. fusiformis* in the Log Pond with the sampler missing the patches in the first year but sampling a dense patch in the 2nd year.

Percent biomass measurements also show substantial differences from Year 1 to Year 2. Of particular interest is the great increase in mollusc biomass in the Log Pond benthic samples; molluscs were nearly absent in the Year 1 sampling at that site. Comparison of the Year 1 and Year 2 cluster analyses suggest that the Log Pond community has changed. In Year 1, much of the clustering of the benthic samples was driven by *Owenia fusiformis* and by the bivalve *Macoma nasuta* (both were much more abundant in the Chuckanut samples than in the Log Pond sites). That has clearly changed since 1) *M. nasuta* did not contribute to the clustering (indicating that its abundance has gone up in the Log Pond) and 2) *O. fusiformis* again contributes to the clustering, but it is in the other direction with much higher abundances in the Log Pond. This suggests that these species have established strong populations in the Log Pond. The Log Pond still has fewer bivalves in general, but the populations appear to be growing.

While there are clear differences between the invertebrate communities in the Log Pond and at the Chuckanut reference site, there is reason to believe that a healthy, functioning community has been established in the sediment cap. Both sites show considerable spatial and temporal variability in their invertebrate fauna. This is a natural characteristic of healthy invertebrate assemblages. The community fluctuations appear to be greater in the Log Pond than in the reference site. This would be expected in a habitat that has been recently disturbed. Over time, we would expect the fluctuations to become less pronounced as the community stabilizes with the addition of a full complement of invertebrate, and vertebrate, species.

Literature cited

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Table I. Analysis of variance for total dry biomass of epibenthic invertebrates. Time had 2 levels (May and June). Site also had two levels (Log Pond and Chuckanut). The assumption of equal variances was violated for this data set. This did not, however, affect our conclusions since no significant effects were found.

Source	SS	df	MS	F	p	Power
Time	1.84E-03	1	1.84E-03	1.93	0.25	0.16
Site	6.39E-03	1	6.39E-03	0.89	0.41	0.10
Time*Site	8.00E-04	1	8.00E-04	0.83	0.42	0.10
Station	2.13E-02	3	7.12E-03	7.46	0.06	0.53
Time*Station	2.86E-03	3	9.54E-04	0.74	0.53	0.18
Error	2.56E-02	20	1.28E-03			
Total	5.88E-02	29				

Table II. Analysis of variance table for dry biomass measurements of invertebrates collected with a ponar grab. Biomass data were log transformed to meet the assumption of equal variances.

Source	SS	df	MS	F	P	Power
Site	1.16	1	1.16	0.38	0.58	0.07
Station	9.15	3	3.05	39.57	< 0.01	
Error	0.77	10	0.07			
Total	11.08	14				

Table III. Analysis of variance table for number of invertebrate species collected in epibenthic samples. The assumption of equal variances was met for these data.

Source	SS	df	MS	F	p	Power
Time	911.3	1	911.3	363.2	< 0.01	
Site	174.0	1	174.0	0.9	0.40	0.10
Time*Site	233.4	1	233.4	93.0	< 0.01	
Station	553.7	3	184.5	73.5	< 0.01	
Time*Station	7.5	3	2.5	0.1	0.94	0.06
Error	410.6	20	20.5			
Total	2290.5	29				

Analysis of variance table for Shannon-Wiener (H') diversity indices calculated for epibenthic samples. The equal variance assumption was met for these data.

Source	SS	df	MS	F	p	Power
Time	0.18	1	0.18	1.48	0.30	0.14
Site	2.61	1	2.61	2.97	0.18	0.23
Time*Site	0.54	1	0.54	4.49	0.12	0.31
Station	2.63	3	0.87	7.19	0.07	0.52
Time*Station	0.36	3	0.12	0.84	0.48	0.19
Error	2.90	20	0.14			
Total	9.22	29				

Table V. Analysis of variance table for the Pielou's (J') evenness indices from epibenthic samples. Unequal variance problems could not be corrected by transformation. Since no results were significant, however, the consequences of this ANOVA violation are minor.

Source	SS	df	MS	F	p	Power
Time	0.089	1	0.089	2.80	0.19	0.22
Site	0.118	1	0.118	1.12	0.36	0.11
Time*Site	0.018	1	0.018	0.58	0.50	0.08
Station	0.313	3	0.104	3.28	0.17	0.28
Time*Station	0.095	3	0.003	1.89	0.16	0.41
Error	0.336	20	0.016			
Total	0.969	29				

Table VI. Analysis of variance table for the number of species collected in ponar grabs. Variances were homogeneous.

Source	SS	df	MS	F	P	Power
Site	1.11	1	1.11	0.01	0.94	0.05
Station	622.22	3	207.40	40.93	< 0.01	
Error	50.66	10	5.06			
Total	673.99	14				

Table VII. Analysis of variance table for the Shannon-Wiener (H') diversity indices calculated from ponar samples. Variances were homogeneous.

Source	SS	df	MS	F	P	Power
Site	0.83	1	0.83	9.09	0.05	
Station	0.27	3	0.09	0.54	0.66	0.12
Error	1.68	10	0.16			
Total	2.78	14				

Table VIII. Analysis of variance table for the Pielou's (J') evenness index. Indices were calculated for each ponar sample. The assumption of equal variances was met.

Source	SS	df	MS	F	P	Power
Site	0.11	1	0.11	10.01	0.05	
Station	0.03	3	0.01	0.44	0.72	0.72
Error	0.24	10	0.02			
Total	0.38	14				

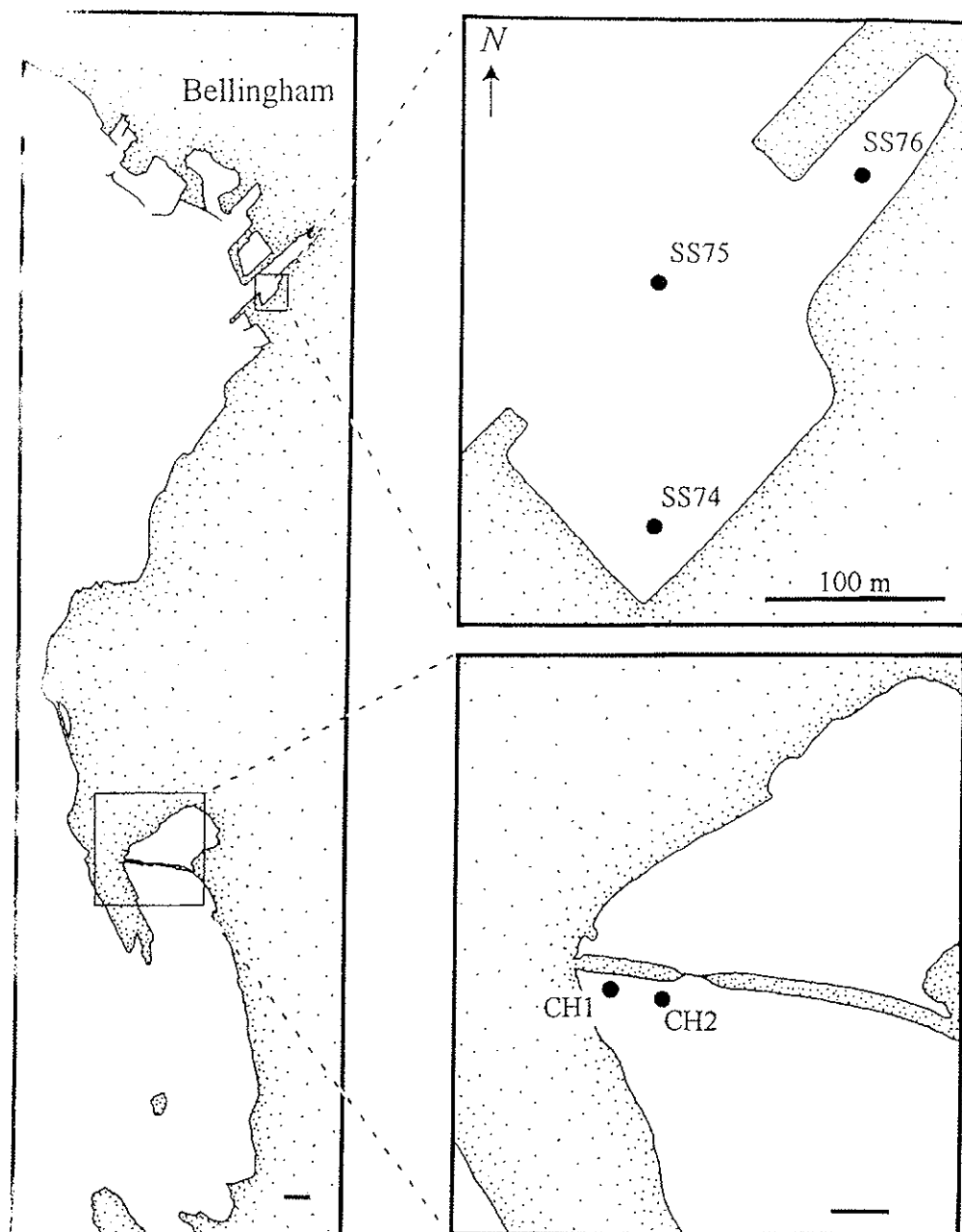
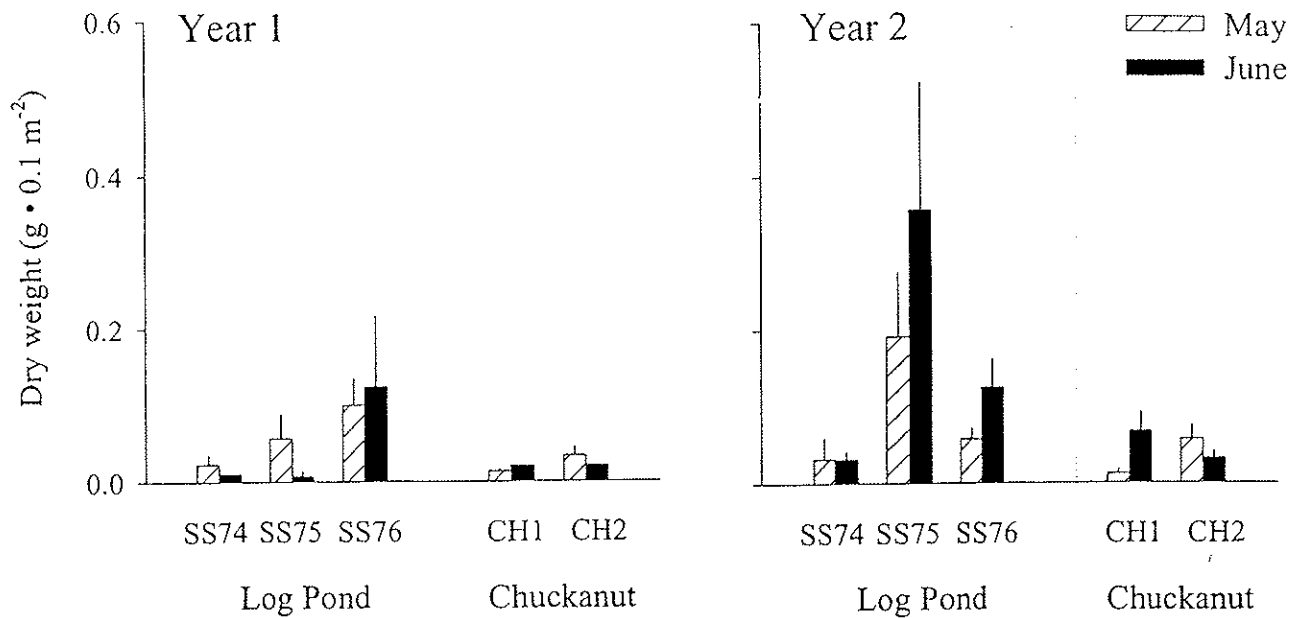


Fig. Study sites in the Log Pond and at the Chuckanut reference site. Scale bars on all figures represent 100 m.

Epibenthic samples



Ponar samples

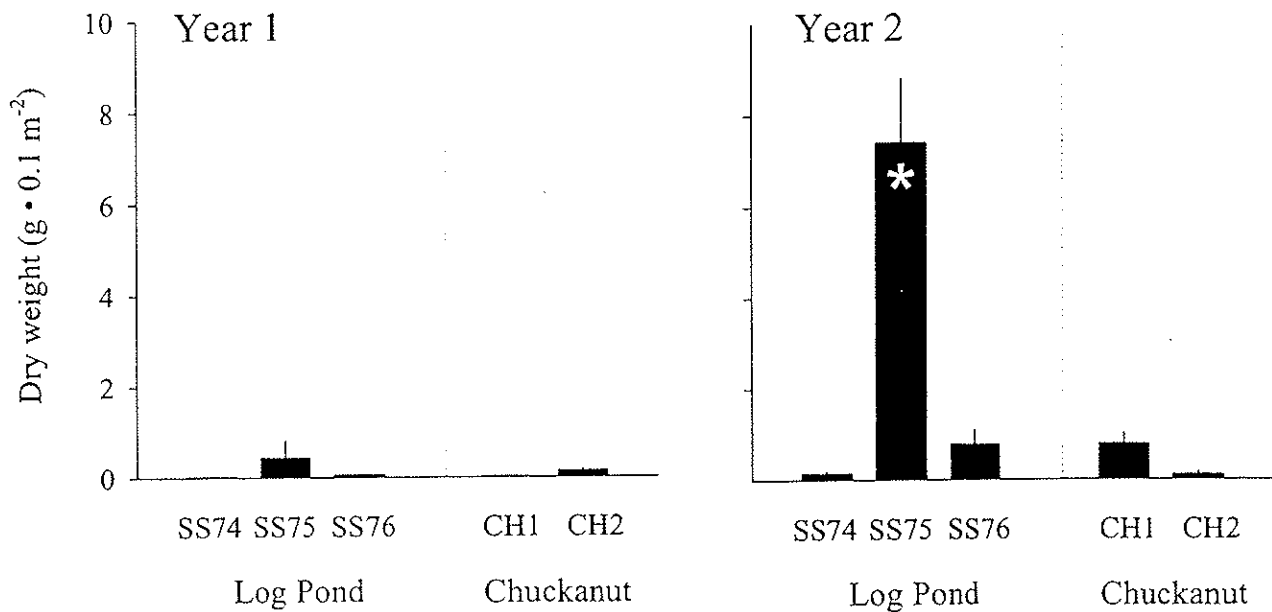
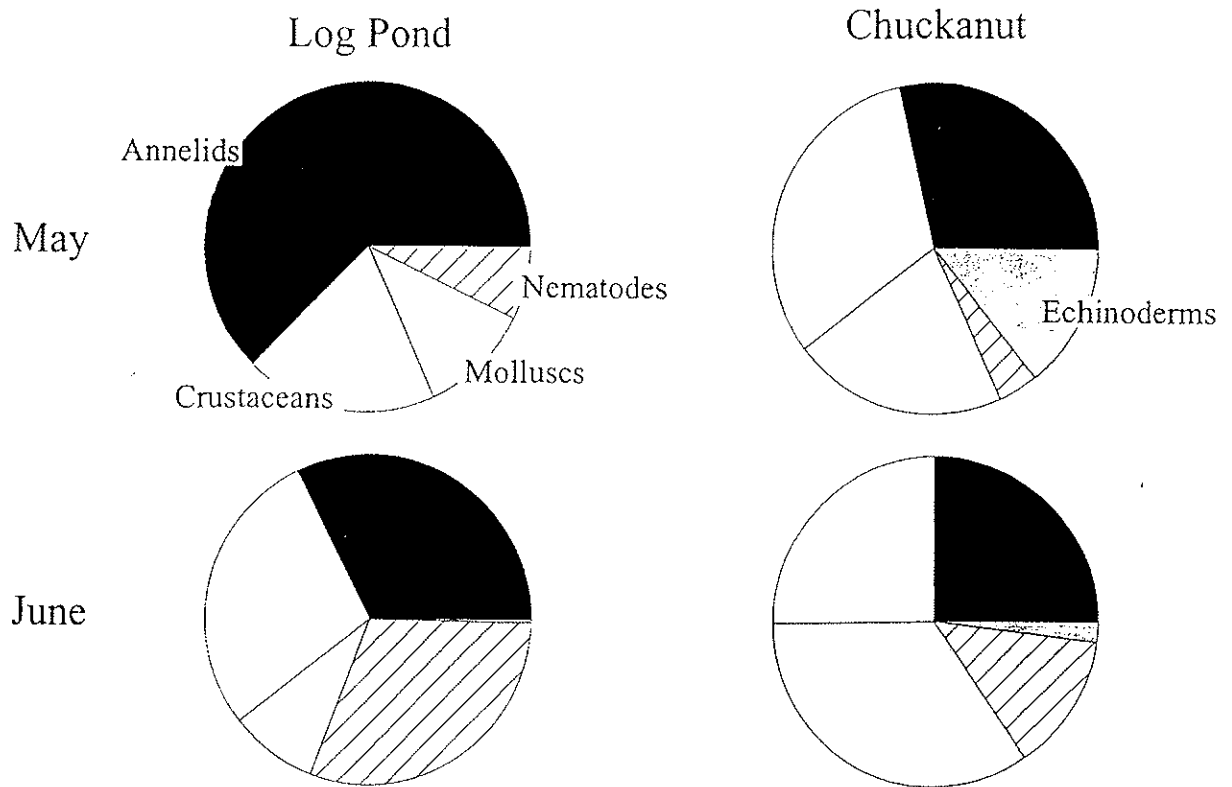


Figure 2. Total dry weights of all invertebrates picked from epibenthic and ponar samples. Standard errors are shown. Because weights of the polychaete *Owenia fusiformis* and its sand tubes were not included in the Year 1 ponar data, we also did not include them in the figure for the Year 2 data. The inclusion of those data would have had a major effect only on the height of the SS75 bar for Year 2 (indicated with an asterisk). The biomass volume of samples from that site (with *O. fusiformis* included) would have averaged $26.3 \text{ g} \cdot \text{m}^{-2}$.

Epibenthic samples



Ponar samples

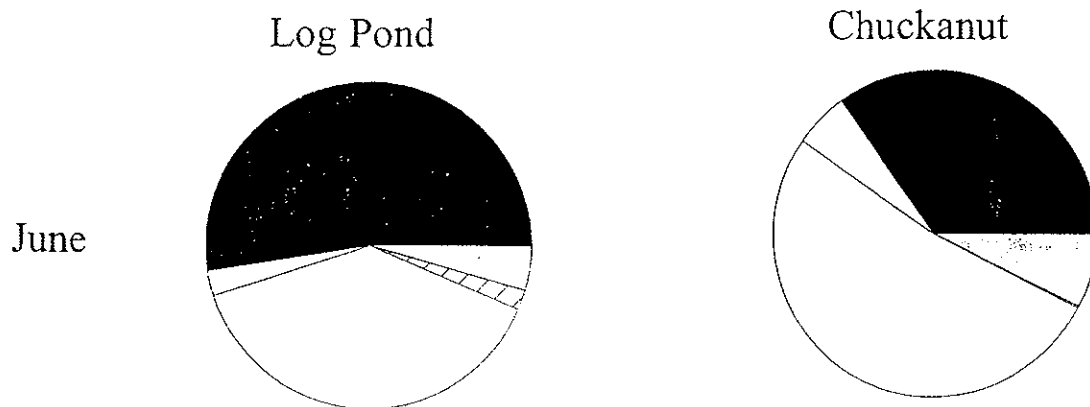


Figure 3. Dry weight composition of invertebrate samples from the Log Pond and Chuckanut study sites.

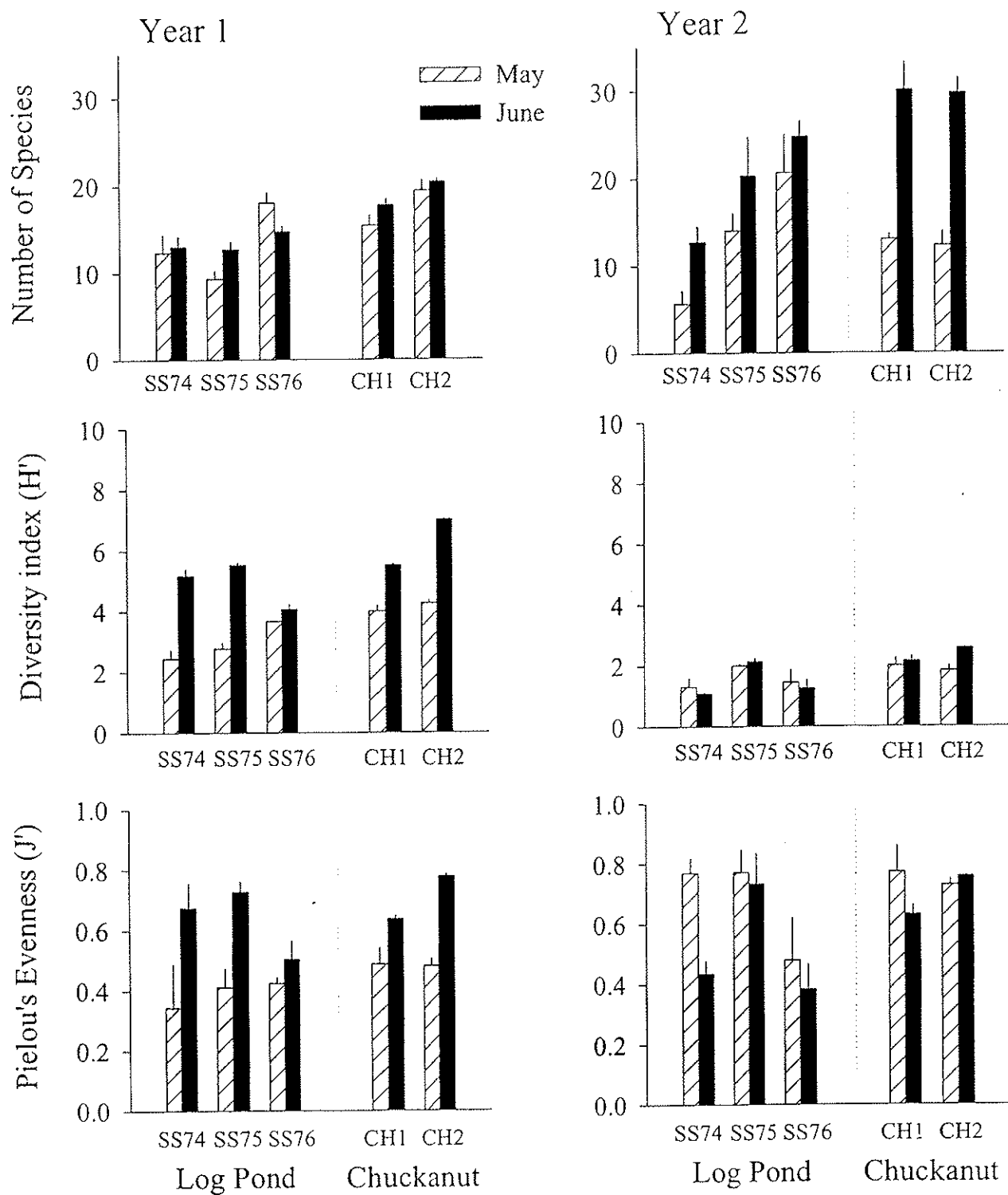


Figure 4. Community composition in epibenthic samples from the Log Pond and Chuckanut sites. Total number of species, the Shannon-Weiner diversity index (H') and Pielou's evenness index (J') are plotted. Standard errors are shown.

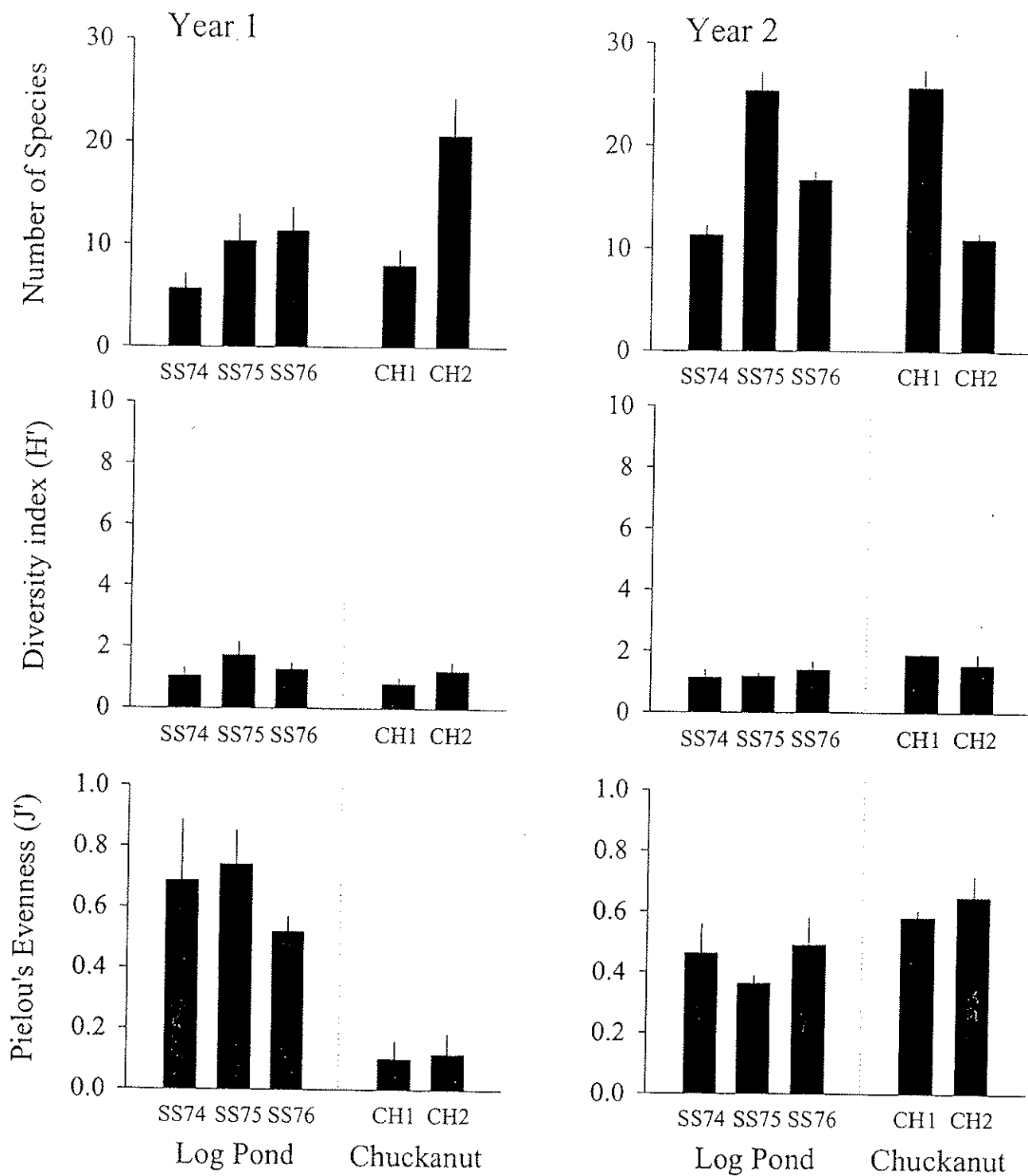
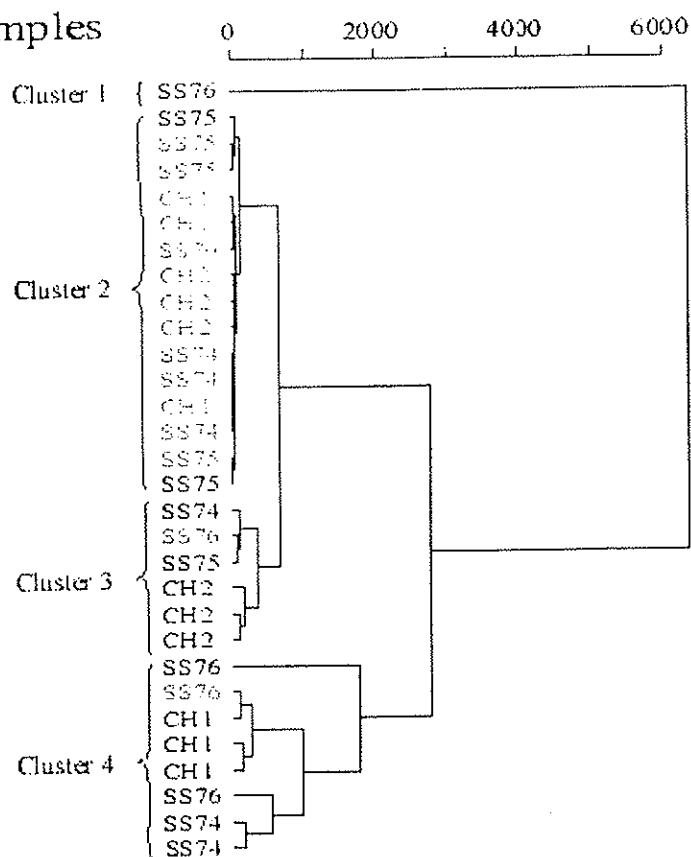


Figure 5. Community indices for ponar samples from the Log Pond and Chuckanut sites. Total number of species, the Shannon-Weiner diversity index (H') and Pielou's evenness index (J') are plotted. Standard errors are shown.

Epibenthic samples



Ponar samples

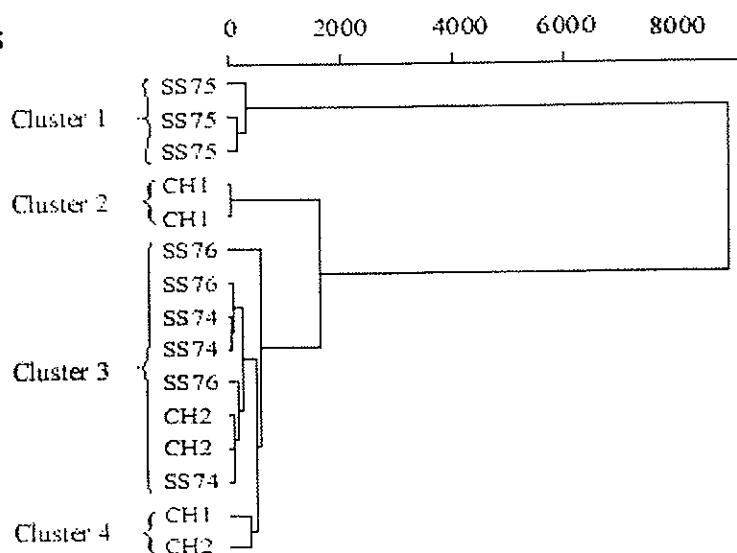


Figure 6. Cluster analysis for invertebrate samples with an epibenthic pump and with a ponar grab in the Georgia Pacific Log Pond and at a Chuckanut Bay reference site. Ward's cluster method with a Euclidean distance measurement was used for the analysis. Red text indicates that the samples were taken in May. The remaining samples were taken in June.

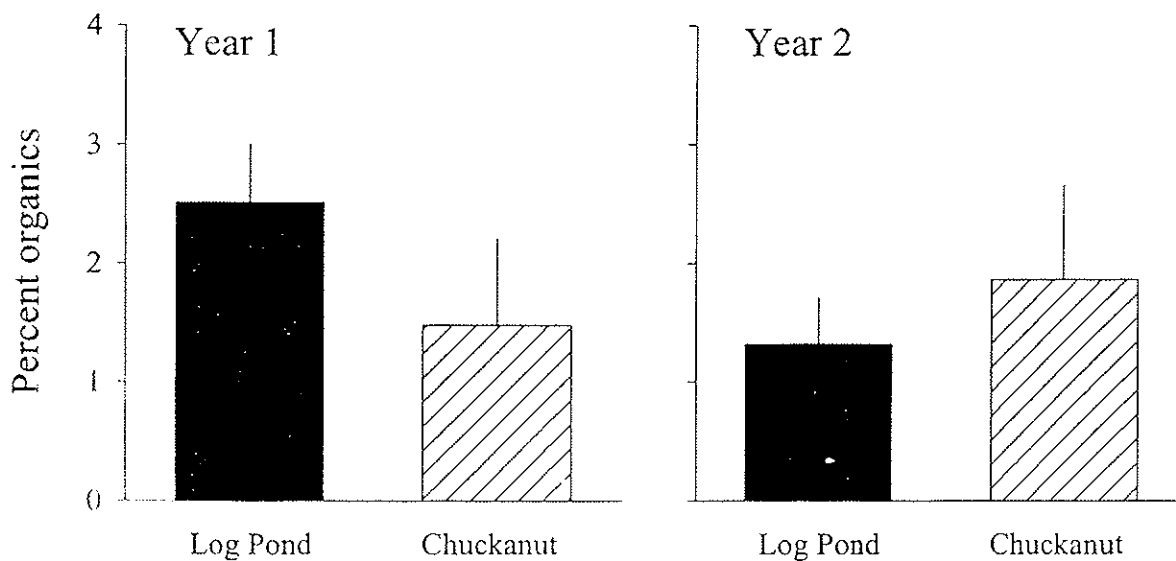
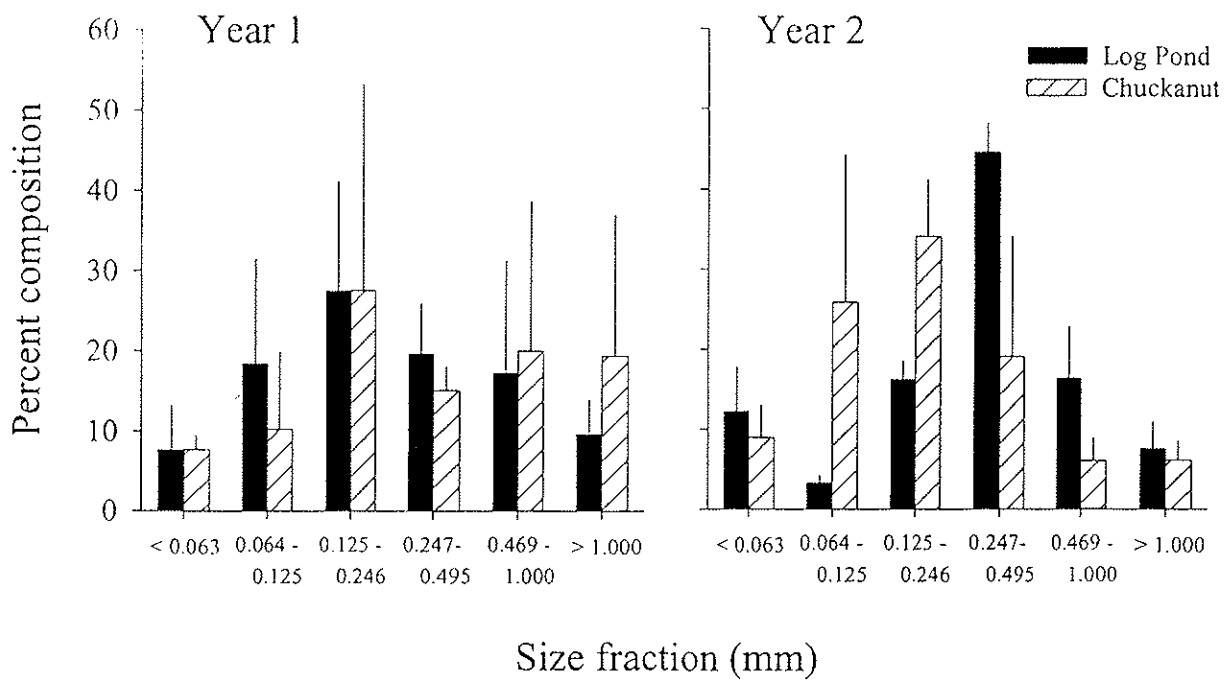


Figure 7. Sediment characteristics at the study sites. Grain-size distribution and percent organic content are plotted. Standard errors are shown.

Appendix I.

Species Checklist for invertebrates collected in the Georgia Pacific Log Pond and in the Chuckanut Reference Site (Year 2).

- Phylum Sarcomastigophora
 - Class Granuloreticulosea
 - Order Foraminiferida
 - Unidentified foraminiferans
- Phylum Nematoda
 - Unidentified nematodes
- Phylum Cnidaria
 - Class Hydrozoa
 - Order Hydroida
 - Family Campanulariidae
 - Obelia* sp.
- Phylum Kinorhyncha
 - Order Cyclorhagida
 - Family Centroderidae
 - Kinorhynchus* sp.
- Phylum Annelida
 - Class Polychaeta
 - Order Capitellida
 - Family Capitellidae
 - Capitella capitata* (Fabricius, 1780)
 - Mediomastus* sp.
 - Family Maldanidae
 - Unknown species
 - Order Cirratulida
 - Family Cirratulidae
 - Cirriformia cirratus* (Muller, 1776)
 - Order Cossurida
 - Family Cossuridae
 - Cossura* sp.
 - Order Chaetopterida
 - Family Chaetopteridae
 - Order Eunicida
 - Family Lumbrineridae
 - Lumbrineris* sp.
 - Order Flabelligerida
 - Family Flabelligeridae
 - Pherusa* sp
 - Order Opheliida
 - Family Opheliidae
 - Armandia brevis* (Moore, 1906)
 - Order Orbiniida
 - Family Orbiniidae
 - Leitoscoloplos pugettensis* (Pettibone, 1957)
 - Order Oweniida
 - Family Oweniidae
 - Owenia fusiformis* (Chiaje, 1841)
 - Order Phyllodocida
 - Family Goniadidae
 - Glycinde polygnatha* (Hartman, 1950)
 - Family Hesionidae

- Ophiodromus pugettensis* (Johnson, 1901)
- Family Nephtyidae
 - Nephtys cornuta* (Berkley and Berkley, 1945)
 - Nephtys longosetosa* (Ørsted, 1843)
- Family Nereidae
 - Platynereis bicanaliculata* (Baird, 1863)
 - Nereis vexillosa* (Grube, 1851)
- Family Pholoididae
 - Pholoe* sp.
- Family Phyllodocidae
 - Phyllodoce castanea* (Marenzeller, 1879)
- Family Polynoidae
 - Harmothoe imbricata* (Linnaeus, 1766)
 - Arctone* sp.
- Family Syllidae
 - Exogone lourei* (Berkeley & Berkeley, 1938)
 - Sphaerosyllis* sp.
- Order Sabellida
 - Family Spirobidae
 - Spirobis* sp.
- Order Spionida
 - Family Spionidae
 - Pygospio* sp.
 - Prionospio jubata* (Blake)
 - Sphiophanes* sp.
 - Polydora* sp.
- Order Terebellida
 - Family Pectinariidae
 - Pectinaria* sp.
 - Family Maldanidae
 - Axiiothella rubrocincta* (Johnson, 1901)
- Class Oligochaeta
 - Unidentified species
- Phylum Mollusca
 - Class Gastropoda
 - Subclass Opisthobranchia
 - Order Pyramidellacea
 - Family Cyclostremellidae
 - Cyclostremella concordia* (Bartsch, 1920)
 - Family Pyramidellidae
 - Odostomia* sp.
 - Turbonilla* sp.
 - Order Cephalaspidea
 - Family Atyidae
 - Haminaea vesicula* (Gould, 1855)
 - Family Cylichnidae
 - Cylichna alba* (Carpenter, 1864)
 - Order Nudibranchia
 - Family Dendronotidae
 - Dendronotus* sp.
 - Subclass Prosobranchia
 - Order Archacogastropoda
 - Family Trochidae
 - Margarites* sp.
 - Family Turbinidae

- Astrea* sp.
- Order Mesogastropoda
 - Family Lacunidae
 - Lacuna vineta* (Montagu, 1803)
 - Family Naticidae
 - Polinices* sp.
 - Unknown sp. 1
 - Family Rissoidae
 - Alvania carpenteri* (Weinkouff, 1885)
- Order Neogastropoda
 - Family Columbellidae
 - Alia gausapata* (Carpenter, 1864)
 - Family Nassariidae
 - Nassarius mendicus* (Gould, 1849)
- Class Bivalvia
 - Order Mytiloida
 - Family Mytilidae
 - Mytilus* sp.
 - Order Veneroida
 - Superfamily Galeommatoidea
 - Family Cardiidae
 - Clinocardium nuttallii* (Conrad, 1837)
 - Nemocardium centifilosum* (Carpenter, 1864)
 - Clinocardium* sp.
 - Family Lucinidae
 - Parvilucina tenuisculpta* (Carpenter, 1864)
 - Family Montacutidae
 - Rocheportia tumida* (Carpenter, 1864)
 - Family Tellinidae
 - Macoma nasuta* (Conrad, 1837)
 - Macoma* sp.
 - Tellina bodegensis* (Hinds, 1845)
 - Family Veneridae
 - Transennella tantilla* (Gould, 1852)
- Class Polyplacophora
 - Order Neoloricata
 - Family Leptochitonidae
 - Leptochitona* sp.
- Phylum Arthropoda
 - Subphylum Crustacea
 - Class Branchiopoda
 - Order Cladocera
 - Family Podonidae
 - Podon leuckarti* (G. O. Sars, 1862)
 - Evadne* sp.
 - Class Ostracoda
 - Suborder Myodocopina
 - Euphilormedes carcharodonta* (Smith, 1952)
 - Suborder Podocopida
 - Unidentified ostracod species 1
 - Unidentified ostracod species 2
 - Unidentified ostracod species 3
 - Class Cirripedia
 - Balanus* sp.
 - Unidentified nauplius larvae

- Unidentified cyprid larvae
- Class Copepoda
 - Order Calanoida
 - Unidentified species
 - Order Harpacticoida
 - Harpacticus* sp.
 - Tisbe* sp.
 - Ectinosoma melaniceps* (Boeck 1865)
 - Orthopsyllus illgi*
 - Nannopus palustris* (Brady, 1880)
- Class Malacostraca
 - Subclass Phyllocarida
 - Order Leptostraca
 - Family Nebaliidae
 - Nebalia pugettensis* (Clark, 1932)
 - Subclass Peracarida
 - Order Cumacea
 - Family Leuconiidae
 - Nippoleucon hinumensis* (Gamo, 1967)
 - Family Nannastacidae
 - Cumella vulgaris* (Hart, 1930)
 - Order Tanaidacea
 - Family Paratanaidae
 - Leptochelia dubia* (Kröyer, 1842)
 - Family Tanaidae
 - Sinelobus stanfordi* (Richardson, 1901)
 - Order Isopoda
 - Suborder Asellota
 - Munna ubiquita* Menzies, 1952
 - Order Amphipoda
 - Superfamily Gammaroidea
 - Family Anisogammaridae
 - Eogammarus* sp.
 - Superfamily Corophioidea
 - Family Corophiidae
 - Corophium spinicorne* Stimpson, 1857
 - Order Decapoda
 - Infraorder Caridea
 - Family Hippolytidae
 - Heptacarpus* sp.
 - Infraorder Anomura
 - Family Paguridae
 - Pagurus* sp.
 - Infraorder Brachyura
 - Unidentified zoea larvae
 - Unidentified megalopa larvae
- Phylum Echinodermata
 - Class Ophiuroidea
 - Order Ophiuroidea
 - Family Amphiuridae
 - Amphiodia occidentalis* (Lyman, 1860)
 - Amphipholis* sp.
 - Class Holothuroidea
 - Order Dendrochirotida
 - Family Phyllophoridae
 - Pentamera populifera* (Stimpson, 1864)

Phylum Chordata
Subphylum Urochordata
Order Doliolida
Class Larvacca
Oikopleura sp.

Appendix II. Organisms collected in May epibenthic samples from three stations in the Georgia Pacific Log Pond (SS-74, SS-75, SS-76) and from two reference stations in Chuckanut Bay (CH-1, CH-2). Unknown specimens were generally juveniles too small to identify.

Annelida

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Arctonoe</i> sp.	0	0	0	0	1
<i>Armandia brevis</i>	0	0	0	0	2
<i>Axiothella rubrocincta</i>	0	0	0	1	0
<i>Capitella capitata</i>	36	0	0	2	3
<i>Exogone lourei</i>	0	4	0	0	1
<i>Glycinde polygnatha</i>	0	0	0	0	1
<i>Harmothoe imbricata</i>	3	8	0	10	16
<i>Mediomastus</i> sp.	0	0	0	0	1
<i>Nephtys longosetosa</i>	5	5	0	5	8
<i>Ophiodromus pugettensis</i>	0	0	0	0	9
<i>Owenia fusiformis</i>	5	4	3	111	16
<i>Pholoe</i> sp.	0	0	0	1	0
<i>Phyllodoce castanea</i>	0	0	2	1	0
<i>Prionospio jubata</i>	1	1	0	0	0
<i>Sphaerosyllis</i> sp.	0	0	0	0	1
<i>Spirorbis</i> sp.	0	0	0	2	1
Unidentified oligochaete	0	0	3	1	9

Mollusca

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Alvania carpenteri</i>	0	9	0	2	1
<i>Clinocardium nuttallii</i>	1	0	0	0	2
<i>Cyclostremella concordia</i>	0	0	0	3	0
<i>Haminaea vesicula</i>	0	0	0	0	1
<i>Lacuna vineta</i>	0	0	0	10	4
<i>Macoma nasuta</i>	0	1	0	36	1
<i>Mytilus</i> sp.	0	0	0	0	1
<i>Nassarius mendicus</i>	0	0	0	0	4
<i>Odostomia</i> sp.	0	2	0	0	0
<i>Parvilucina tenuisculpta</i>	0	2	0	0	4
<i>Polinices</i> sp.	0	0	0	0	15
<i>Rocheportia tumida</i>	16	66	0	5	84
<i>Tellina bodegensis</i>	1	0	0	12	14
<i>Transennella tantilla</i>	0	0	0	3	0
Unknown gastropod #1	0	0	0	0	3

Crustacea

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Balanus</i> sp.	0	1	1	2	11
<i>Corophium spinicorne</i>	0	1	0	1	4
<i>Cumella vulgaris</i>	7	2	5	1	5
<i>Ectinosoma melaniceps</i>	1	0	3	1	0

<i>Eogammarus</i> sp.	24	10	1	0	2
<i>Evadne</i> sp.	0	10	0	0	0
<i>Harpacticus</i> sp.	15	0	2	0	34
<i>Heptacarpus</i> sp.	10	2	3	0	0
<i>Leptochelia dubia</i>	1	1	0	0	0
<i>Munna ubiquita</i>	0	3	0	4	0
<i>Nannopus palustris</i>	0	0	0	1	4
<i>Nebalia pugettensis</i>	0	3	0	0	0
<i>Nippoleucon hinumensis</i>	0	0	0	1	1
<i>Pagurus</i> sp.	1	0	0	0	0
<i>Podon leuckarti</i>	0	0	1	16	5
<i>Tisbe</i> sp.	0	2	0	1	2
Unidentified carangid copepod	1	1	0	0	3
Unidentified ostracod species 1	2	0	0	0	1
Unidentified cyprid larva	1	0	0	0	4
Unidentified zoeae larva	5	3	0	1	0

Miscellaneous

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
Unidentified foraminiferans	13	18	0	0	441
Unidentified nematodes	105	35	29	24	843
<i>Obelia</i> medusa (Cnidaria)	0	0	0	1	0
<i>Amphiodia occidentalis</i> (Echinodermata)	1	0	0	0	0
<i>Amphipholis</i> sp. (Echinodermata)	2	9	0	5	1
<i>Oikopleura</i> sp. (Urochordata)	0	1	0	0	0

Appendix III. Organisms collected in June epibenthic samples from three stations in the Georgia Pacific Log Pond (SS-74, SS-75, SS-76) and from two reference stations in Chuckanut Bay (CH-1, CH-2).

Annelida

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Armandia brevis</i>	6	15	0	2	1
<i>Axiiothella rubrocincta</i>	0	0	0	0	2
<i>Capitella capitata</i>	2	0	3	22	0
Chaetopteridae (Family)	1	0	0	0	0
<i>Exogone lourei</i>	1	0	12	1	24
<i>Glycinde polygnatha</i>	7	0	0	0	9
<i>Harmothoe imbricata</i>	7	1	0	1	0
<i>Leitoscoloplos pugettensis</i>	0	0	3	0	0
<i>Lumbrineris</i> sp.	0	0	0	1	0
<i>Mediomastus</i> sp.	0	0	0	0	16
<i>Nephtys cornuta</i>	0	0	0	0	1
<i>Nephtys longosetosa</i>	10	1	0	0	48
<i>Nereis vexillosa</i>	0	0	1	1	0
<i>Ophiodromus pugettensis</i>	0	0	0	0	1
<i>Owenia fusiformis</i>	111	167	3	151	195
<i>Pectinaria</i> sp.	0	1	0	0	0
<i>Pherusa</i> sp.	0	0	0	3	0
<i>Pholoe</i> sp.	0	0	0	4	0
<i>Platynereis bicanaliculata</i>	0	1	0	0	0
<i>Prionospio jubata</i>	2	0	0	0	0
<i>Polydora</i> sp.	8	1	0	2	3
<i>Spirorbis</i> sp.	1	1	0	5	1
Unidentified oligochaete	2	6	84	5	16

Mollusca

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Alia gausapata</i>	0	0	0	1	0
<i>Alvania carpenteri</i>	4	1	0	16	3
<i>Clinocardium nuttallii</i>	0	0	6	12	0
<i>Clinocardium</i> sp.	34	117	0	18	48
<i>Dendronotus</i> sp.	0	2	0	0	0
<i>Lacuna vineta</i>	1	29	0	0	0
<i>Macoma nasuta</i>	5	54	0	0	0
<i>Macoma</i> sp.	28	1	0	0	0
<i>Mytilus</i> sp.	0	1	0	2	0
<i>Neocardium centifilosum</i>	0	2	0	0	0
<i>Parvilucina tenuisculpta</i>	1	50	0	9	0
<i>Polinices</i> sp.	3	62	0	2	12
<i>Rocheportia tumida</i>	418	387	0	39	204
<i>Tellina bodegensis</i>	0	9	0	4	0
Unknown gastropod #2	4	0	0	7	8

Crustacea

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Balanus</i> sp.	14	7	2	6	6
<i>Corophium spinicornis</i>	2	11	0	5	0
<i>Cumella vulgaris</i>	64	396	0	3	13
<i>Ectinosoma melaniceps</i>	25	1	2	0	146

<i>Eogammarus</i> sp.	23	162	0	0	0
<i>Euphilomedes carcharodonta</i>	2	0	0	0	0
<i>Evadne</i> sp.	1	17	0	0	0
<i>Harpacticus</i> sp.	367	676	1681	6	4737
<i>Heptacarpus</i> sp.	1	0	0	0	6
<i>Leptochelia dubia</i>	13	0	0	0	0
<i>Munna ubiquita</i>	19	0	0	5	0
<i>Nannopus palustris</i>	160	352	46	0	78
<i>Nebalia pugettensis</i>	5	0	0	1	0
<i>Nippoleucon hinumensis</i>	0	0	7	1	4
<i>Orthopsyllus illogic</i>	40	23	1	0	12
<i>Podon leuckarti</i>	147	139	33	6	13
<i>Sinelobus stanfordi</i>	1	0	0	0	2
<i>Tisbe</i> sp.	121	205	65	11	317
Unidentified carangid copepod	48	22	28	17	43
Unidentified ostracod species 1	0	40	0	0	0
Unidentified ostracod species 2	0	15	0	0	0
Unidentified ostracod species 3	131	0	0	0	0
Unidentified nauplius larva	30	7	0	0	1
Unidentified cyprid larva	37	20	4	5	135
Unidentified zoea larvae	5	4	2	0	7
Unidentified megalopa larva	0	0	1	0	0

Miscellaneous	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
Unidentified foraminiferans	1112	120	2	104	728
Unidentified nematodes	1180	273	1688	198	8787
<i>Obelia medusa</i> (Cnidaria)	0	1	0	0	0
<i>Kinorhynchus</i> sp. (Kinorhyncha)	0	0	0	0	2
<i>Amphipholis</i> sp. (Echinodermata)	2	0	0	2	0

Appendix IV. Organisms collected in ponar samples from three stations in the Georgia Pacific Log Pond (SS-74, SS-75, SS-76) and from two reference stations in Chuckanut Bay (CH-1, CH-2).

Annelida

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Armandia brevis</i>	18	5	2	0	1
<i>Capitella capitata</i>	7	0	47	16	22
<i>Cirriformia cirratus</i>	2	0	0	7	0
Chaetopteridae (Family)	2	0	0	0	0
<i>Cossura</i> sp.	0	0	0	15	0
<i>Exogone lourei</i>	0	0	1	0	0
<i>Glycinde polygnatha</i>	16	0	3	30	13
<i>Harmothoe imbricata</i>	0	0	0	13	0
<i>Leitoscoloplos pugettensis</i>	37	0	6	0	2
Maldanidae (Family)	0	0	0	0	3
<i>Mediomastus</i> sp.	1	2	0	25	0
<i>Nephtys longosetosa</i>	9	8	0	74	11
<i>Owenia fusiformis</i>	93	22	0	6227	125
<i>Pectinaria</i> sp.	1	0	0	8	0
<i>Pholoe</i> sp.	1	0	5	0	1
<i>Phyllodoce</i> sp.	0	0	9	0	0
<i>Prinospio jubata</i>	0	0	2	0	0
<i>Pygospio</i> sp.	6	0	2	0	5
<i>Sphiophanes</i> sp.	3	0	0	0	0
<i>Spirorbis</i> sp.	15	0	0	75	0

Mollusca

	Station				
	CH-1	CH-2	SS-74	SS-75	SS-76
<i>Alia gausapata</i>	3	0	0	0	0
<i>Alvania carpenteri</i>	90	0	2	540	107
<i>Astrea</i> sp.	0	1	0	0	0
<i>Cylichna alba</i>	1	1	0	33	0
<i>Clinocardium nuttalli</i>	69	313	1	0	4
<i>Clinocardium</i> sp.	13	0	0	0	0
<i>Haminaea vesicula</i>	1	0	1	0	5
<i>Lacuna vineta</i>	1	0	6	0	0
<i>Leptochitona</i> sp.	0	0	0	0	1
<i>Macoma nasuta</i>	2	4	7	0	2
<i>Macoma</i> sp.	0	0	0	0	6
<i>Margarites</i> sp.	3	0	0	0	0
<i>Mytilus</i> sp.	0	0	0	13	0
<i>Nassarius mendicus</i>	2	10	0	18	0
Naticidae (Family)	0	2	0	0	0
<i>Neocardium centifilosum</i>	0	0	0	1	0
<i>Odostomia</i> sp.	4	0	0	17	0
<i>Parvilucina tenuisculpta</i>	15	0	0	75	0
<i>Rochefortia tumida</i>	1409	62	7	182	25
<i>Tellina bodegensis</i>	57	0	15	91	14
<i>Transennella tantilla</i>	7	0	0	0	0
<i>Turbonilla</i> sp.	0	0	0	2	0
Unknown gastropod #1	0	0	0	1	1
Unknown gastropod #2	0	0	1	6	0

Crustaceana

	CH-1	CH-2	Station SS-74	SS-75	SS-76
<i>Balanus</i> sp.	26	4	0	7	8
<i>Corophium spinicorne</i>	0	1	0	22	10
<i>Cumella vulgaris</i>	67	22	2	5	10
<i>Eogammarus</i> sp.	18	2	0	16	0
<i>Euphilomedes carcharodonta</i>	24	0	0	3	0
<i>Heptacarpus</i> sp.	0	0	1	0	0
<i>Leptochelia dubia</i>	62	1	0	6	0
<i>Munna ubiquita</i>	25	0	0	19	0
<i>Nannopus palustris</i>	0	0	8	0	0
<i>Nebalia pugettensis</i>	0	1	0	0	0
<i>Nippoleucon hinumensis</i>	3	0	1	0	7
<i>Sinelobus stanfordi</i>	0	0	0	9	0
<i>Tisbe</i> sp.	0	0	1	0	0
Unidentified calanoid copepod	0	0	0	4	0
Unidentified ostracod species 1	2	0	0	0	0
Unidentified cyprid larva					
Unidentified magalopa larva	0	0	0	1	0

Miscellaneous

	CH-1	CH-2	Station SS-74	SS-75	SS-76
Unidentified foraminiferans	557	2	8	111	8
Unidentified nematodes	408	8	268	517	654
<i>Obelia</i> medusa (Cnidaria)	0	0	0	69	0
<i>Amphiodia occidentalis</i> (Enchinodermata)	0	0	0	0	0
<i>Amphipholis</i> sp. (Enchinodermata)	4	0	0	0	0
<i>Pentamera populifera</i> (Enchinodermata)	0	0	0	5	0
<i>Oikopleura</i> sp. (Chordata)	0	4	0	0	0